

APPLICATION
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TITLE: ADVANCED POWER DISTRIBUTION SYSTEM

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ADVANCED POWER DISTRIBUTION SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part application of, and claims priority to, U.S. Application Serial No. 09/955,405, filed on September 12, 2001.

TECHNICAL FIELD

5 This invention relates to a system for improving power quality and distribution, and more particularly to a power quality system including a harmonic cancellation unit.

BACKGROUND

10 Modern electronic systems present conflicting requirements to power providers and the distributions systems they serve. On the one hand, many of the computer and telecommunication systems being brought on-line today present non-linear loads to the source that serves them. These non-linear loads reduce the quality of power locally and else where on the grid. Additionally, the non-linear loads result in wasted power and increased wiring requirements. On the other hand, many of these same loads are intolerant of the very quality problems that they create. Therefore there is a need for systems that reduce the disturbances created by the load while simultaneously improving the power to such loads.

15 One of the most common nonlinear loads is the input of a DC/DC converter on a personal computer or a telecommunications power supply. Typically composed of an input rectifier followed by smoothing capacitor, these systems draw current from the source at the peaks of the input voltage waveform. The result is a current waveform with a significantly higher RMS value than a linear load drawing the same power. This higher current in turn drives power systems to be designed with larger generation and distribution capacity.

20 Additional issues that arise due to non-linear loads are distortion of the voltage waveform on the power grid at locations close to such loads. Because power grids are not designed to accommodate the large number of non-linear loads that are on-line today, the system impedance causes voltage drops at the extremities of the power grid.

25 Systems to accomplish these goals are seen in U.S. Patent Nos. 5,343,080 and 5,434,455. These systems describe two (or more) secondary windings on the transformer to accomplish the cancellation of harmonics. The secondary windings must, to some extent, share the load. This

places a significant burden on system maintenance. When loads are removed the system must be rebalanced to provide the appropriate harmonic cancellation attribute.

Similarly, such systems must be tuned to address specific load generated harmonics. This consists of physically changing the output connections of the transformer. In addition to the set-up time required to implement such a system, this same problem presents itself when loads are removed or replaced by others with different characteristics.

The filters that are part of the above referenced patent also do not address the issue of harmonic currents in the neutral connection. Harmonic currents, which can significantly exceed the phase currents, are by-products of nonlinear loads. Harmonic currents in the neutral connection significantly increase the cost of system wiring. For example, for three-phase power, the wiring may be increased, as much as twice in diameter, to accommodate an unbalanced load. In older buildings that were not designed for modern power requirements, heating problems in existing neutral connections can present safety issues, like fire as a result of the fact that unbalanced loads for three-phase power can significantly increase neutral currents and resistance heating.

SUMMARY

The present invention addresses the shortcomings of present day power systems with a harmonic cancellation transformer having a filter, transfer switch, disconnection devices and surge suppression devices. These components can be combined in various ways to form systems that protect the critical load from a range of power quality events, e.g., from black outs to surges due to lightning. Additionally, these components combine to present a load to the power source that has significantly reduced levels of harmonic distortion.

The harmonic cancellation transformer includes a single secondary winding that can be wound to cancel the third and triplen harmonics of the excitation frequency. These harmonics represent a significant component of harmonic distortion in most systems. The transformer attenuates these harmonics in the primary and therefore on the power grid. When triplen harmonics are cancelled, the power grid is advantageously cleaner.

The filter in the secondary of the transformer can serve several functions. First, harmonics that may be present in the secondary circuit are attenuated – this can include all harmonics, not just the triplen harmonics. Second, the filter attenuates these harmonics in the secondary circuit thereby mitigating their deleterious affects and reducing the amount of wiring

necessary, for example, in the neutral connections. Coupled with the single secondary form of the harmonic transformer, the system requires only one filter element. Typically downstream of filter, the transient suppression components provide protection to the load from over voltage events on the primary side.

5 In one embodiment of the invention, a harmonic cancellation unit is connected to a uninterrupted transfer switch (UTS). The transfer switch provides appreciably uninterrupted power from a plurality of sources. The UTS is setup to automatically switch from the presently utilized source to an alternate source in a time span short enough to be undetectable to sensitive loads. In this configuration, the harmonic cancellation unit further improves the power quality
10 received by the load. Control and remote monitoring can be included to further improve system performance and flexibility.

The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

15 DESCRIPTION OF DRAWINGS

FIG. 1 schematically depicts an Advanced Power Distribution System, according to the present invention.

FIG. 2 schematically depicts an Advanced Power Distribution System including an Uninterruptible Transfer Switch (“UTS”) and a Harmonic Cancellation Module.

20 **FIG. 3** schematically depicts a Harmonic Cancellation Unit including a Zig-Zag transformer with common mode and differential mode passive filters for use in Power Distribution Systems.

FIG. 4 schematically depicts a Harmonic Cancellation Unit including a Delta-Wye transformer with common mode and differential mode passive filters for use in Power
25 Distribution Systems.

DETAILED DESCRIPTION

Figure 1 illustrates an embodiment of an Advanced Power Distribution System **100** according to the present invention. The Advanced Power Distribution System **100** can include a primary **101** and alternate source(s) **102**, protective devices **212**, Harmonic Cancellation Module
30 **214**, Lightning/Surge protector **216**, disconnects **218**, **220**, and **224**, transfer switch **10**, remote

monitoring (GRAM) **118**, control module **116**, Transient Voltage Surge Suppressor (TVSS) **230**, load distribution **228**, and the critical load(s) **232**.

Sources **101**, **102** or **103** may include power from a utility company, or generated power from diesel generators, fuel cells, nuclear power plants, and other well known sources. This power is then fed into the transfer switch **10**. The transfer switch **10** is used to transfer between any one of the sources. This allows power from the alternate source(s) to be switched to the critical load(s) **232** in the event the preferred source **101** exhibits a loss of power. The transfer switch **10** can be a SCR, Triac, IGBT, Relay, Contactor, an Uninterruptible Transfer Switch (UTS), or other well known transfer switch.

The output of the transfer switch **10** is connected to the primary of the Harmonic Cancellation Module **214** through disconnect device(s) **224**. As described further below, the Harmonic Cancellation Module **214** attenuates harmonics in the Advanced Power System **100**. This can be accomplished, for example, by use of a transformer and appropriate filters (not shown) as described further below. Protective devices **212** protect the system from harmful electrical failures, e.g., short circuit conditions caused by the critical loads **232**, or by a transformer short, or from a failed transfer switch **10**. Device(s) **212** and **224** could be circuit breaker(s), fuse(s), vacuum breaker(s) or other well known current limiting device(s).

Lightning/Surge Arrestor **216** is a device that shunts high energy/noise pulses into the grounding system of the building. For example, exemplary devices are capable of handling currents of 40kA or greater. For example, Lightning/Surge Arrestor **216** can be Metal Oxide Varistors (MOV's), lightning arrestors, active clamping devices, or other well known clamping devices.

Disconnects **220** and **224** are used to provide a maintenance mechanism to allow power to be diverted around the transfer switch **10**, for example, in the event of failure. Transient Voltage Surge Suppressor (TVSS) **230** is a device that shunts energy/noise pulses between line and neutral connected to the critical load **232**. Typically, this device is capable of handling currents of 500A or greater. These devices can include Metal Oxide Varistors (MOV's), lightning arrestors, active clamping devices, or other well known clamping devices.

Load distribution **228** allows a plurality of critical loads **232** to be connected to the system **100**. The load distribution **228** allows single phase loads, dual phase loads, as well as three phase loads to be connected to system **100**. This can be achieved, for example, by single molded case switches or circuit breakers or by combinations of 42 pole panels.

Figure 2 depicts another embodiment of the Advanced Power Distribution System **100**. While shown as single lines, the power sources **101**, **102**, **103** can be multi-phase or single-phase. Switches **110**, **111**, **112** isolate each of the power sources from the load **232**. A source designated as the “preferred source” **101** is the power source that will be selected by the transfer switch **10** as long as the preferred source **101** meets certain pre-determined power quality requirements such as amplitude, phase, and frequency stability. In this embodiment, the transfer switch **10** is an Uninterruptible Transfer Switch (“UTS”), which means that the load **232** will not experience an appreciable voltage outage during switching of the power sources. Protective devices and lightning/surge protectors (not shown) can be added between the power sources and the load **232** to protect the load **232** from transient events that may occur up-stream of the UTS **10**.

A choke **119** is in-line with the load **232**. The choke **119** is typically a passive, low loss, element that performs no significant function during normal operation of the UTS **10**. The choke **119** can pass current from the selected source to the load. The choke **119** may be a standard choke or a coupled inductor. The choke can also be replaced with any of a variety of well-known transformers used in power applications, like isolation transformers.

Rectifiers **107**, **108**, and **109** are coupled to the source side of the switches **110**, **111**, **112**. During normal operation, i.e., non-transient power conditions, any of the rectifiers **107**, **108**, **109** can feed an inverter **114** from any power source, typically one with the highest voltage. Because the inverter **114** can be controlled in the manner described below, in a low power, “stand-by” state, the current passed through the rectifiers can be minimal and therefore power dissipation is advantageously low. During stand-by operation, the inverter **114** can also be used to regulate voltage to the load **232** and used to improve power factor of the load **232**. When the power sources are being switched, i.e., during transient conditions, the inverter **114** is used provide power to the load **232**.

The inverter **114** input can include a bank of electrolytic capacitors (not shown) used in conjunction with the rectifiers to sufficiently “smooth” the input voltage to the inverter **114**. During normal operation, the inverter **114** maintains a sinusoidal voltage at the output of filter **115** and the auto transformer **117** substantially equal in amplitude at the load **232**. Therefore, the aggregate affect of the UTS **10** on system power during normal operation is minimal.

Referring again to figure 2, the system **100** can include the addition of energy storage element **121**. Energy storage element **121** provides energy to the inverter independent of all

sources. In this way, the energy storage element **121** enables the system to “ride-through” instances when none of the power sources are able to provide power to the load. In this way, the system can be configured so that the alternative power source need not be readily available, for example, an engine-driven generator or turbine. Thus, the energy storage element **121** can provide energy to the inverter while and until the alternative source is able to generate power. Energy storage element **121** can consist of any well-known components, e.g., generator, turbine, electro-chemical capacitors, double layer capacitors, battery, electrolytic capacitors, hybrid capacitor/battery, fuel cell, super capacitor, HED (high energy-density) capacitor, etc. For example, the battery can be any well known type like lead acid, lithium, NiCAD, NiMH, etc.

Control module **116** can control the operation of the system **100**, including switches **110**, **111**, and **112**. The control module **116** can sense power quality from the sources **101**, **102**, **103** as well as their respective power output quality, for instance, voltage, current, phase and frequency. For example, using DQ transformation as well as individual line-line criteria, the power quality of all of the input power sources can be monitored by control module **116**.

Operators can program the control module **116** to operate elements of the UTS **10** and the Harmonic Cancellation Unit **214** in accordance with the requirements of the load **232**. That is, such programs can be altered depending upon the system operational requirements of the load **232**, for example, how sensitive the load **232** is to changes in power quality. When the power quality of the presently utilized source falls outside of user-determined bounds for a predetermined time period, the control module **116** can initiate the process of switching to another source. For that reason, the control module **116** is coupled to and can control actuation of switches **110**, **111**, and **112**. Because the control module **116** can monitor all sources, an alternate source can be identified at all times. Software to facilitate the functions of control module **116** can reside in numerous places in system **100**, including remote monitoring **118** and control module **116**.

The control module **116** can also monitor power quality coming into the inverter **114**. Likewise, the control module **116** can monitor power quality coming out of the inverter **114** (not shown). This may be particularly useful in controlling the operation of the inverter **114** so that power quality, like voltage, current, frequency and phase is monitored and maintained by controlling the operation of the inverter **114**. The control module **116** can also activate, operate and deactivate the inverter **114**. The control module **116** can also monitor and control the operation of the energy storage element **121**.

The control module **116** can also monitor power quality input to the load **232**. This will help the control module **116** to prevent undesirable power quality from reaching the load **232**. Those of skill in the art will appreciate that the control module **116** can perform additional functions like maintenance and diagnostic functions of any or all system **100** elements. For example, the control module **116** can include memory functions to keep a history of the Advanced Power Distribution System **100** operation and the associated variables.

Referring again to figure 2, remote monitoring unit **118** can be coupled to any and all components of the system **100**. During all modes of operation, the remote monitoring unit **118**, also referred to as GRAM (Global Remote, Advanced Monitoring) provides the functions of remotely monitoring and/or controlling system **100**, including UTS **10** and Harmonic Cancellation Module **214**. Remote monitoring unit **118** can transmit and/or receive system **100** information concerning some or all of the system **100** state variables, for example, operating amplitudes, frequencies, integrity of system components, availability and selection of power sources, and power quality including, but not limited to input voltage, input current, input power (watts, VA, VARS), input voltage distortion, input current distortion, input THD, input Power Factor, input surge events, input brown outs, input black outs, output voltage, output current, output power (watts, VA, VARS), output voltage distortion, output current distortion, output THD, output Power Factor, output surge events, brown outs, black outs. GRAM **118** can also be utilized to control or change some or all of the system **100** state variables, including but not limited to UTS **10** and Harmonic Cancellation Module **214** state variables, like inverter **114** operation, source selection, harmonic frequency attenuation or excitation, etc. GRAM **118** can transmit and receive this information to external remote devices to allow control and monitoring of the system **100** using any well-known communication technology, e.g., satellite link, cellular link, telephone link, etc. Additionally, GRAM **118** can communicate to remote devices like laptop computers or similar devices, via several different communication protocols such as TCP/IP, MODBUS, etc.

For example, once the control module **116** has detected an out of specification condition in the preferred source **101**, e.g., transient power condition, the control module can initiate steps directed to changing power sources without appreciable interruption in power supplied to the load **232**. A signal from the control module **116** can trigger the inverter **114** to active mode. During the normal state, the inverter **114** can be in a standby mode passively synchronized to the power source.

Upon receipt of the command to control output voltage, for example from the control module **116**, the inverter **114** draws power from the one or more of the rectifiers **107, 108, 109** and begins furnishing power to the load **232**. Following activation of the inverter **114**, the control module **116** can issue a command resulting in the opening of switch **110** thereby
5 disconnecting the failing source **101** from the load **232**. In a like manner, the control module **116** can monitor and control the operation of the Harmonic Cancellation Module **214** in order to provide power to load **232** in accordance with the invention. For example, the control module **116** can detect degraded power quality, for example by the presence of undesired harmonic frequencies or out of specification in neutral currents. Likewise, the control module **116** can
10 actuate, for example, variable components in filters **364** and/or **366** to attenuate the unwanted harmonics thereby improving system **100** performance so that load **232** receives improved power quality.

Embodiments of the Harmonic Cancellation Module **214** are depicted in Figure 3 and Figure 4. Physical construction of the transformer, core, coils, and filters are not shown as this is
15 well understood by those skilled in the art. Figure 3 describes the Harmonic Cancellation Module **214** that can attenuate triplen harmonics. Triplen harmonics are odd harmonics which are the odd multiples of the third harmonic, e.g., 3^{rd} , 9^{th} , 15^{th} , 21^{st} , etc. The Harmonic Cancellation Module **214** depicted in Figure 3 also attenuates the 5^{th} , 7^{th} , 11^{th} harmonics. These harmonics are attenuated by the combination of the transformer **502**, common mode filter **366**,
20 and differential mode filter **364**.

The transformer **502** is constructed utilizing three phase primary input windings **308, 310, 312**, configured in a Delta configuration, with multiple taps, and three phase output windings **314, 316, 318, 320, 322, 324** configured in an interconnected star ("Zig-Zag") winding. The windings for both the primary and secondary windings can be constructed by any well known
25 means, for example from copper, aluminum, wire or foil.

The windings are placed on a core structure **370** that can be made from steel, silicon steel, amorphous metal or other well known magnetic materials. Core structure **370** can be either a single structure, or three separate structures. The primary Delta configuration shown is wired by connecting one end of coil **308** to one end of coil **310**, and one end of coil **310** to one end of coil
30 **312**, and finally by connecting one end of coil **312** to one end of coil **308** as depicted in figure 3. The three phase inputs **302, 304, 306** are connected to the primary windings **308, 310, 312** as shown in figure 3. The interconnected star winding (Secondary) is arranged in core structure **370**

by phase shifting the secondary windings, allowing the triplen harmonics to be eliminated from being induced into the primary winding. The secondary winding is configured by sharing the individual phase windings in different legs of the core structure 370.

5 'Phase A' output of the transformer is connected as follows: Coil 314 is wound on the 'Phase A' leg of the core 370 and coil 320 is wound on the 'Phase B' leg of the core 370. One end of coil 314 is connected to one end of coil 320 at 326. The other end of 314 is connected to the neutral output of transformer 502, along with coil 318, and coil 322. The phase output of the transformer for 'Phase A' is connected from one end of coil 316 to one end of inductor 344.

10 'Phase B' output of the transformer is connected as follows: Coil 318 is wound on the 'Phase B' leg of the core 370 and coil 324 is wound on the 'Phase C' leg of the core 370. One end of coil 318 is connected to one end of coil 324 at 330. The other end of 318 is connected to the neutral output of transformer 502, along with coil 314, and coil 322. The phase output of the transformer for 'Phase B' is connected from one end of coil 320 to one end of inductor 340.

15 'Phase C' output of the transformer is connected as follows: Coil 322 is wound on the 'Phase C' leg of the core 370 and coil 316 is wound on the 'Phase A' leg of the core 370. One end of coil 322 is connected to one end of coil 316 at 328. The other end of 322 is connected to the neutral output of transformer 502, along with coil 314, and coil 318. The phase output of the transformer for 'Phase C' is connected from one end of coil 324 to one end of inductor 348.

20 The transformer 502 alone can only effectively cancel triplen harmonics as described earlier, and only with balanced loads. The Wye connected loads contribute a large percentage of 3rd harmonics in which transformer 502 can cancel from the secondary to the primary windings. However, these harmonics, known as zero sequence harmonics, add up in the neutral conductor of the secondary circuit, and as such must be rated for at least 1.73 times the line current. These currents have been known to overheat transformers, as well as building wiring, and associated protective devices. With modern power systems, it is hard for the end user to ensure that the loads are connected to balance the output seen by the secondary winding of transformer 502, as these loads could be a plurality of single phase loads. In order to handle the imbalance of the three phase output, and to attenuate the harmonics in the neutral side of the loads, one embodiment of the invention includes a filter 364 as part of the Harmonic Cancellation Module 114.

30 The filter 364 effectively attenuates the 3rd harmonic in the neutral line. However, it should be noted that the filter is capable of being tuned to this and other harmonics. As depicted

in Figure 3, the filter **364** is a three pole, L/C type, band reject filter. The 3rd harmonic is attenuated by filter components, capacitors **338, 340, 342** and inductors **332, 334, 336**. The values of these components can vary based on the design requirements, and available components. Typically, these values can be selected by determining the desired corner frequency calculated from the equation $f_c = (\frac{1}{2}\pi) \text{ Square Root}(LC)$, where L is the inductance and C is the capacitance. The inductors **332, 334, 336** can be made of different core materials such as ferrite, iron, powdered iron, steel, silicon steel, amorphous metals, and other known materials. The inductors **332, 334, 336** could also be a single inductor, or a plurality of inductors to make the desired inductance. The capacitors **338, 340, 342** can be of different materials such as polyester, metalized polyester, polycarbonate, metalized polycarbonate, oil filled, paper, ceramic, mica, or other well known materials. The capacitors **338, 340, 342** could also be a single capacitor, or a plurality of capacitors to make the desired capacitance. The tuned filter diverts the unwanted harmonic neutral current into the ground conductor **372**, thus attenuating unwanted harmonics, reducing the amount of the particular harmonics making the neutral current equal to or less than the line current.

Load **232** can predominantly generate the 5th, 7th, and 11th harmonics. These harmonics do not return to the neutral, and are not treated by filter **364** or by transformer **502**. In order to attenuate and treat these harmonics, filter **366** can be employed. Filter **366** can be designed to effectively attenuate harmonics greater than 250 Hz, and frequencies greater than 250Hz are typically attenuated at 40dB/decade. However, it should be noted that filter **366** is capable of being tuned to this and other frequencies. Filter **366** can be a L/C type, low pass filter as shown in Figure 4. Components in the filter **366** attenuate harmonics. The components include capacitors **350, 352, 354** and inductors **344, 346, 348**. As discussed above in relation to filter **364**, the values of these components can vary based on the design requirements, and available components. Typically, these values can be selected by determining the desired corner frequency calculated from the equation $f_c = (\frac{1}{2}\pi) \text{ Square Root}(LC)$, where L is the inductance and C is the capacitance. The inductors **344, 346, 348** can be made of different core materials such as ferrite, iron, powdered iron, steel, silicon steel, amorphous metals, and other known materials. The inductors **344, 346, 348** could also be a single inductor, or a plurality of inductors to make the desired inductance. The capacitors **350, 352, 354** can be of different materials such as polyester, metalized polyester, polycarbonate, metalized polycarbonate, oil filled, paper, ceramic, mica, or other well known materials. The capacitors **350, 352, 354** could also be a

single capacitor, or a plurality of capacitors to make the desired capacitance. The tuned filter attenuates load generated harmonics from conducting into the secondary of transformer **502**, thus attenuating these harmonics from being seen on the primary side of transformer **502**.

Although filters **364** and **366** are depicted as passive elements, those of skill in the art will appreciate that these filters can employ active elements, e.g., microprocessor controlled adjustable filters. In this way, the filters **364** and **366** can be arranged to create adjustable filters that can have variable characteristics, like frequency cutoffs. This is advantageous in applications where unwanted harmonics and neutral currents vary and therefore filters **364** and **366** can be optimized "on the fly" to respond to transient conditions thereby optimizing power quality delivered to load **232**. As described earlier, control module **116** and/or remote monitoring **118** can be utilized to adjust the Harmonic Cancellation Module **214**.

Figure 4 depicts another embodiment of the Harmonic Cancellation Module **214** which can attenuate harmonics as in Figure 3, with an exception. Transformer **504** does not attenuate triplen harmonics. The construction of transformer **504** is similar to the construction of transformer **502** of figure 3 except for the connection of the secondary windings. 'Phase A' output of the transformer is connected as follows: Coil **304** is wound on the 'Phase A' leg of the core **370**. One end of coil **404** is connected to the neutral output of transformer **504**, along with coil **406**, and coil **408**. The phase output of the transformer for 'Phase A' is connected from one end of coil **404** to one end of inductor **344**.

'Phase B' output of the transformer is connected as follows: Coil **406** is wound on the 'Phase B' leg of the core **370**. One end of coil **406** is connected to the neutral output of transformer **504**, along with coil **404**, and coil **408**. The phase output of the transformer for 'Phase B' is connected from one end of coil **406** to one end of inductor **340**.

'Phase C' output of the transformer is connected as follows: Coil **408** is wound on the 'Phase C' leg of the core **370**. One end of coil **408** is connected to the neutral output of transformer **504**, along with coil **404**, and coil **406**. The phase output of the transformer for 'Phase C' is connected from one end of coil **408** to one end of inductor **348**.

Referring again to figure 2, and as discussed above, control module **116** interrogates the system **100** for power quality including, but not limited to input voltage, input current, input power (watts, VA, VARS), input voltage distortion, input current distortion, input THD, input Power Factor, input surge events, input brown outs, input black outs, output voltage, output current, output power (watts, VA, VARS), output voltage distortion, output current distortion,

output THD, output Power Factor, output surge events, brown outs, black outs. The control module **116** transmits this information to remote monitoring (GRAM) **118** so that system **100** can be remotely monitored and/or controlled. Additionally, as discussed above, software can be incorporated into both control module **116** and remote monitoring **118** so that the system automatically controls system **100** to compensate for any and all preprogrammed out of specification conditions. Likewise, remote monitoring **118** can be utilized to download upgraded software remotely, altered system **100** performance specification criteria remotely, or like information remotely thereby resulting in a more manageable and dynamic system **100**.

The control module **116** and remote monitoring **118** can interrogate the system **100** to include but not limited to temperature conditions of transformers in Harmonic Cancellation Module **214**, status of disconnects **220** and **224**, status of protective device(s) **212**, lightning surge protector **216**, transfer switch **10**, voltages and currents associated with load distribution **228**, and status of transient voltage surge suppressor **230**. The control module **116** and/or the remote monitoring **118** can include storage media to store data concerning the performance of system **100**. As discussed above, the remote monitoring **118** can transmit the system **100** performance data via the internet, phones lines, fiber optic lines, wireless means, or by any well known communication media.

A number of embodiments of the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. .